REMARKS

Claim Rejections – 35 USC § 112

Claims 1-24 and 36-46 were rejected under 35 U.S.C. §112, first paragraph, "because the specification, while being enabling for switching between an implicit method and an explicit method of simulation within a finite element analysis computer program (page 15, lines 1-16; page 17, lines 6-12; page 18, lines 2-9), does not reasonably provide enablement for every conceivable means for switching between an implicit method and an explicit method of finite element simulation. The specification does not enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make the invention commensurate in scope with these claims. Claims 1, 14 and 36 are single means/step claims. Therefore consequently cover every conceivable means for switching between an implicit method and an explicit method of finite element simulation, while the specification discloses at most only those means of switching known to the inventor. See MPEP 2164.08(a)."

MPEP 2164.08(a) applies to single means claims and cites *In re Hyatt*, 708 F.2d 712. *Hyatt* indicates that a "single means claim" is a claim drafted in "means-plus-function" format yet reciting only a single element instead of a combination. *Id*. Not a single one of claims 1-24 and 34-36 that the Examiner has rejected on this basis are drafted in means plus function format under 35 U.S.C. §112, paragraph 6. This rejection therefore lacks merit and is moot.

Claims 1-46 were also rejected under 35 U.S.C. §112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention.

It appears as if this rejection is based upon a lack of understanding of a select few claim terms. These terms are the same as those the Examiner has chosen to construe in a section entitled "Claim Interpretation." The claim terms are discussed below in response to the Examiner's claim interpretation, and the Examiner is kindly referred to those comments in response to this indefiniteness rejection. As will be seen below and in the specification itself, the selected claim terms are well known to those of ordinary skill in the art and are described in the specification. Therefore, it is kindly asserted that the claims do particularly point out and distinctly claim the subject matter to one of ordinary skill in the art.

DRAWING AMENDMENTS

Submitted herewith is a marked up version of the amended drawings, in accordance with 37 C.F.R. §1.121(d). The amended drawings are in two sheets, labeled as Figs. 2 and 3. Also submitted are replacement sheets.

The Examiner has objected to the drawings because of both the position and size of the page numbering on sheets 2 and 3. The Examiner stated that the drawing numerals are not larger than the reference numerals and that the location should be on the right, not in the center.

Applicant has amended the drawings in order to make the font of the drawing number larger. However, the location has not been changed because there is no room to put the drawing number of the right hand side, and it is not required by law. The relevant law in 37 CFR § 1.84 indicates that the preferred position is in the center, not on the right:

> (t) *Numbering of sheets of drawings*. The sheets of drawings should be numbered in consecutive Arabic numerals, starting with 1, within the sight as defined in paragraph (g) of this section. <u>These numbers, if present, must be placed in the middle of the top of the sheet, but not in the margin</u>. The numbers <u>can</u> be placed on the right-hand side if the drawing extends too close to the middle of the top edge of the usable surface. The drawing sheet numbering must be clear and larger than the numbers used as reference characters to avoid confusion.

Claim Interpretation

The Examiner has put forth his interpretation of numerous claim elements on page 5 of the current Office Action.

It should be noted that the terms the Examiner has chosen to construe are well known in the art, and that the Applicant has not acted as his own lexicographer with regard to those selected terms. The Applicant has not defined or intended to define any of the terms with a definition other than that commonly known and understood in the art. In order to act as his own lexicographer, a patentee has to clearly set forth an explicit definition of the term different from its ordinary meaning. See, e.g., Tex. Digital Sys., Inc. v. Telegenix, Inc., 308 F.3d 1193, 1204 (Fed. Cir. 2002), cert. denied, 538 U.S. 1058 (2003).

The well known explicit method has been described in detail in this application. The description is in accord with the well known meaning. One portion of the application that describes the explicit method is from page 4 line 19 to page 6 line 9. That portion does not define or re-define the explicit method, but describes it, along with other items, and is excerpted below.

> The explicit method is based on a statement of dynamic equilibrium: force is equal to the product of mass and acceleration. This condition is applied independently at each node point. Thus, at each node point, forces are assembled, and the acceleration of each node is computed simply by dividing by nodal mass. This process is repeated as the solution is incrementally advanced in time, integrating the nodal accelerations to obtain velocity and displacement. In order for this solution to remain accurate, a limit is placed on the maximum size of the time step. This limit, known as the Courant condition, is typically less than one microsecond in automotive applications. This means that over one million time steps are often required to simulate one second of structural response.

The explicit solution procedure can be described mathematically as follows: A statement of dynamic equilibrium may be written as a balance between inertial, internal and external forces at each node point in the model

$$\mathbf{Ma} + \mathbf{f}^{\text{int}}(\mathbf{u}) = \mathbf{f}^{ext}$$

where $\mathbf{M}$ is the nodal mass matrix, $\mathbf{a}$ is the nodal acceleration vector, and $\mathbf{f}^{\text{int}}(\mathbf{u})$ and $\mathbf{f}^{ext}$ are the discrete vectors of internal and external forces, and for brevity only $\mathbf{f}^{\text{int}}$ is expressed as a function of the nodal displacement vector $\mathbf{u}$. The solution is advanced by solving the above equation for the acceleration at time (n), and then applying the central difference method to obtain nodal velocity and displacement vectors

$$\mathbf{v}^{(n+1/2)} = \mathbf{v}^{(n-1/2)} + \mathbf{a}^{(n)}\Delta t$$

$$\mathbf{u}^{(n+1)} = \mathbf{u}^{(n-1)} + \mathbf{v}^{(n+1/2)}\Delta t$$

The Courant condition provides a limit for the maximum stable time step Δt, which can be written as

$$\Delta t < \frac{h}{c}$$

where h is the material sound speed, and c is the size of the smallest element in the model.

An advantage of the explicit method is that relatively small amount of computer CPU and memory resources are required, since a stiffness matrix is not used. Another advantage of the explicit method is that convergence is not a problem, since no equilibrium iterations are necessary.

A disadvantage of the explicit method is that static equilibrium can only be approximated. Another disadvantage of the explicit method is that the Courant time step size limit requires potentially hundreds of thousands of time steps to be computed during each simulation, which significantly slows the solution process. Yet another disadvantage of the explicit method is that techniques for accelerating the solution process, such as mass scaling, introduce artificial dynamic effects which are difficult to quantify and control.

The well known Implicit method has also been discussed in detail. The implicit method is characterized by the formation of a stiffness matrix to represent the interaction of nodal motions within the structure…[page 2, lines 10-18] The mathematical expression of implicit method can also be found in page 2, line 22, page 3, lines 6, 12, 15. The characteristics of implicit methods has been discussed on page 4, lines 5-18.

The implicit method is characterized by the formation of a stiffness matrix to represent the interaction of nodal motions within the structure. In the implicit solution process, the stiffness matrix is assembled, its inverse is computed, and this inverse is applied to an array of nodal forces to produce a solution of nodal displacements. For nonlinear problems, these displacements are tested to verify that they satisfy the governing equations of motion. If the equations are not satisfied, an iterative procedure is applied to refine the accuracy of the solution. When a satisfactory solution is finally obtained, the iterative process is said to have converged. Successful convergence of these iterations is not guaranteed and can be very difficult in practice.

The implicit solution procedure can be described mathematically as follows: A statement of static equilibrium may be written as a balance of internal and external forces at each node point in the model

$$\mathbf{f}^{\text{int}}(\mathbf{u}) = \mathbf{f}^{ext}$$

where $\mathbf{f}^{\text{int}}(\mathbf{u})$ and $\mathbf{f}^{ext}$ are the discrete vectors of internal and external forces, and for brevity only $\mathbf{f}^{\text{int}}$ is expressed as a function of the nodal displacement vector $\mathbf{u}$. At each load step (time step) during the simulation, a displacement vector is sought which satisfies equilibrium according to the above equation. The equations describing this iterative search are obtained by performing a first order Taylor series expansion about the displacement solution at iteration (i+1), and moving known terms from iteration (i) to the right

$$\mathbf{u}^{(i+1)} = \mathbf{u}^{(i)} + \Delta\mathbf{u}$$

$$\mathbf{f}^{\text{int}}\left(\mathbf{u}^{(i)} + \Delta\mathbf{u}\right) = \mathbf{f}^{ext}$$

$$\frac{\partial \mathbf{f}^{\text{int}}}{\partial \mathbf{u}}\left(\mathbf{u}^{(i)}\right)\Delta\mathbf{u} = \mathbf{f}^{ext} - \mathbf{f}^{\text{int}}\left(\mathbf{u}^{(i)}\right)$$

$$\mathbf{K}\left(\mathbf{u}^{(i)}\right)\Delta\mathbf{u} = \mathbf{R}^{(i)}$$

where $\mathbf{K}$ represents the stiffness matrix of the structure, $\mathbf{R}$ represents the out-of-balance or residual force vector, and $\Delta\mathbf{u}$ represents the increment or change in displacement which advances the solution from iteration (i) to iteration (i+1).

The solution is initialized for time step (n+1) using the equilibrium displacement solution from the previous time step (n)

$$\mathbf{u}_{(n+1)}^{(0)} = \mathbf{u}_{(n)}$$

The solution is then advanced iteratively by successively solving for the displacement increment, and then updating the total displacement

$$\Delta\mathbf{u} = \mathbf{K}^{-1}\left(\mathbf{u}^{(i)}\right)\mathbf{R}^{(i)}$$

$$\mathbf{u}^{(i+1)} = \mathbf{u}^{(i)} + \Delta\mathbf{u}$$

When the correct equilibrium solution is found, both the residual force vector and the displacement increment become zero. Norms of these vectors are used to evaluate the accuracy of a solution during the iteration process, and to test for convergence of the equilibrium iterations. The product of displacement increment and residual force can be computed to give the incremental internal energy of the model, which can be monitored for excessive growth to detect divergence of the equilibrium iteration process.

An advantage of the implicit method is that a solution which satisfies static equilibrium can be computed directly. Another advantage of the implicit method is that there is no algorithmic limit to time step size. Loads can typically be applied in tens or hundreds of steps, rather than millions of steps.

A disadvantage of the implicit method is that a stiffness matrix must be formed and inverted. Assembling and inverting the stiffness matrix in a typical application requires a relatively large amount of computer CPU and memory resources. For example, in a typical automotive application, the dimensions of the stiffness matrix can be more than one million by one million. Another disadvantage of the implicit method is that convergence of the nonlinear

equilibrium iteration process is not guaranteed. Successful convergence at each step of the solution requires proper choice of load step (time step), and good performance of the numerical models for material behavior and contact interaction between parts. Each simulation presents a new set of difficulties, so that reliable solutions are not always available even for expert users of the method.

While these portions of the specification have been provided for convenience, other portions of the specification also may be relevant, and the selected terms should not be limited by the description above, but should be construed according to the meaning understood by those skilled in the art, as stated previously.

In response to the Examiner's interpretation of "automatic switching" and "switching occurs automatically," the Examiner is kindly asked to refer to the section entitled "Automatic Switching" beginning on page 12 and the figures that are referred to in that section and also to the section entitled "Implicit-Explicit Switching Overview" beginning on page 11 12 and the figures that are referred to in that section.

Additionally, the Examiner's interpretation of the term "solution to a fine element simulation is reached" as "the total simulation time is reached" is unduly narrow. Reaching the total simulation time is only one of many inputs that may be used in determining if a solution is reached.

Claim Rejections – 35 USC § 102

Karafillis

Claims 1, 2, 5, 7-10, 12, 14, 16, 18-21, 23, 25, 27, 29-32, 34, 36, 38 and 40-43 were rejected under 35 U.S.C. §102(e) as being anticipated by US Patent No. 6,353,768 to Karafillis et al. ("Karafillis").

However, Karafillis does not teach switching between an implicit method and an explicit method. Nor does it teach that such switching would occur automatically. In fact, Karafillis

does not even appear to teach the use of the implicit method, let alone any switching to or from the implicit method. The portions that the Examiner has cited as teaching the implicit method simply do not describe the implicit method. Specifically, the Examiner has cited Column 4, lines 23-29 and column 5 lines 18-24 as teaching the implicit method. Column 4 lines 23-29, as reproduced below, does not teach the implicit method.

> The workpiece **116** is defined as a membrane comprising a mesh of triangular elements, according to an exemplary embodiment of the invention. The membrane models a surface which runs through the middle point across the thickness of the workpiece. Each element is associated with a thickness that can change during the formation process. Each triangular element is defined by three nodes. Each node is defined by position coordinates. The mesh is typically constructed with the well known Delaunay triangulation method. During the simulation of the forming process, the displacement, velocity, and acceleration of each node is monitored and recorded. A force, such as from friction, is applied to the node as an acceleration calculated with Newton's second law and the appropriate mass. Based on this data, the stresses and strains on each triangular element, as well as the thickness of each element are calculated.

Column 5 lines 18-24, reproduced below, also does not teach the implicit method.

> The drawbead restraining force, normal force, and thinning strain at the drawbead exit have been found to be a function of the workpiece material and the drawbead geometry. The drawbead restraining force, normal force, and thinning strain can thus be determined by these parameters, without modeling the process of pulling the workpiece across the drawbead in each case. Preferably, the process of modeling the pulling of the workpiece across the drawbead is conducted initially for a number of values of the ratio t/r for all materials of interest, where t is the thickness of the workpiece sheet and r is the drawbead radius. For each value of t/r for a particular workpiece material, the restraining force, normal force, and thinning strain are obtained and plotted, as shown in FIGS. **7**, **8**, and **9**.

The only mention of the implicit method in Karafillis is in the background section, where Karafillis describes deficiencies in the implementation of a prior system. See Column 1, lines 45-50. While Karafillis does teach that the prior art includes an explicit version, and an implicit version, these are described as separate individual versions - *Karafillis does not teach* a single

version having both implicit *and* explicit functionality. Furthermore, Karafillis does not teach any switching (manual or automatic) between implicit and explicit methodology (or vice versa) at any time, whether in its description of prior systems or of the invention of Karafillis. Therefore, Karafillis cannot anticipate any of the above listed claims.

LS-Dyna Manual

Claims 1, 3, 4, 6, 7, 11, 13, 14, 15, 17, 18, 22, 24, 25, 26, 28, 29, 33, 35, 36, 37, 39, 40, and 44 were rejected under 35 U.S.C. §102(b) as being anticipated by LS-DYNA Keyword User's Manual by Livermore Software Technology Corporation.

Each of the pending of claims 1-35, as amended, either directly or by virtue of dependency, recites automatically switching between the implicit and explicit method two or more times, i.e. from implicit to explicit to implicit, or from explicit to implicit to explicit. The LS-DYNA User's Manual does not teach this. In practice, a currently implemented embodiment of the present invention may switch back and forth between methods many times during a finite element analysis or simulation. This technique is invaluable in arriving at a precise solution and has not been taught by any of the cited prior art, including the version of the LS-DYNA manual cited by the Examiner (which is not hereby admitted to be prior art).

As seen in the background section, the implicit method has certain advantages and drawbacks as does the explicit method. At certain points during a simulation it will be advantageous to use the implicit method, whereas at other points it would be advantageous to use the explicit method. Simply using one method or the other would be inferior. Moreover, the ability to switch back and forth, automatically, between the methods will maximize the strengths of each method, while minimizing the drawbacks. The automatic switching can be triggered by any number of criteria, as is specified in the dependent claims. For instance: dependent claim 8 claims automatically switching from the implicit method to the explicit method if the number of iterations exceeds a predetermined threshold number; dependent claim 9 claims monitoring the internal energy of the model during iterations of the implicit method and automatically switching from the implicit method to the explicit method if the internal energy exceeds a predetermined threshold number; and dependent claim 10 claims automatically switching from the explicit method back to the implicit method if the length of time exceeds a predetermined threshold time

period. By automatically switching based upon these criteria, the system can determine that it is best to switch to the other method to continue the simulation. In other words, the system may automatically determine that the best way to proceed, at any given point, would be in the other of the methods and switch to that method. For example, if achieving convergence with the implicit method is proving difficult, the system can automatically switch to the explicit method, where it is not a problem (since no equilibrium iterations are necessary). If a condition exists that indicates that the simulation would thereafter once again benefit from the advantages of the other method, it will switch back to that method. This maximizes the advantages of both of the methods, while minimizing the drawbacks, and results in a more precise solution than would otherwise be possible. As mentioned in the specification, each simulation presents a unique set of difficulties, and reliable solutions are not always available even for expert users of prior systems. The automatic switching of the present invention is a major advantage in overcoming these difficulties. This is not taught by any of the cited references, either explicitly or inherently, and is not obvious in light of the teachings of any of the cited references.

Each of the pending of claims 36-46, either directly or by virtue of dependency, as amended, claims "instructions for monitoring the internal energy of the model during iterations using the implicit method and automatically switching from the implicit method to the explicit method if the internal energy exceeds a predetermined threshold number." This is also not taught by any of the cited references, either explicitly or inherently and is not obvious in light of the teachings of any of the cited references. Therefore, claims 36-46 cannot be anticipated or obvious and are in condition for allowance.

CONCLUSION

Accordingly, it is believed that this application is now in condition for allowance and an early indication of its allowance is solicited. However, if the Examiner has any further matters that need to be resolved, a telephone call to the undersigned attorney at 415-318-1168 would be appreciated.

Respectfully submitted,

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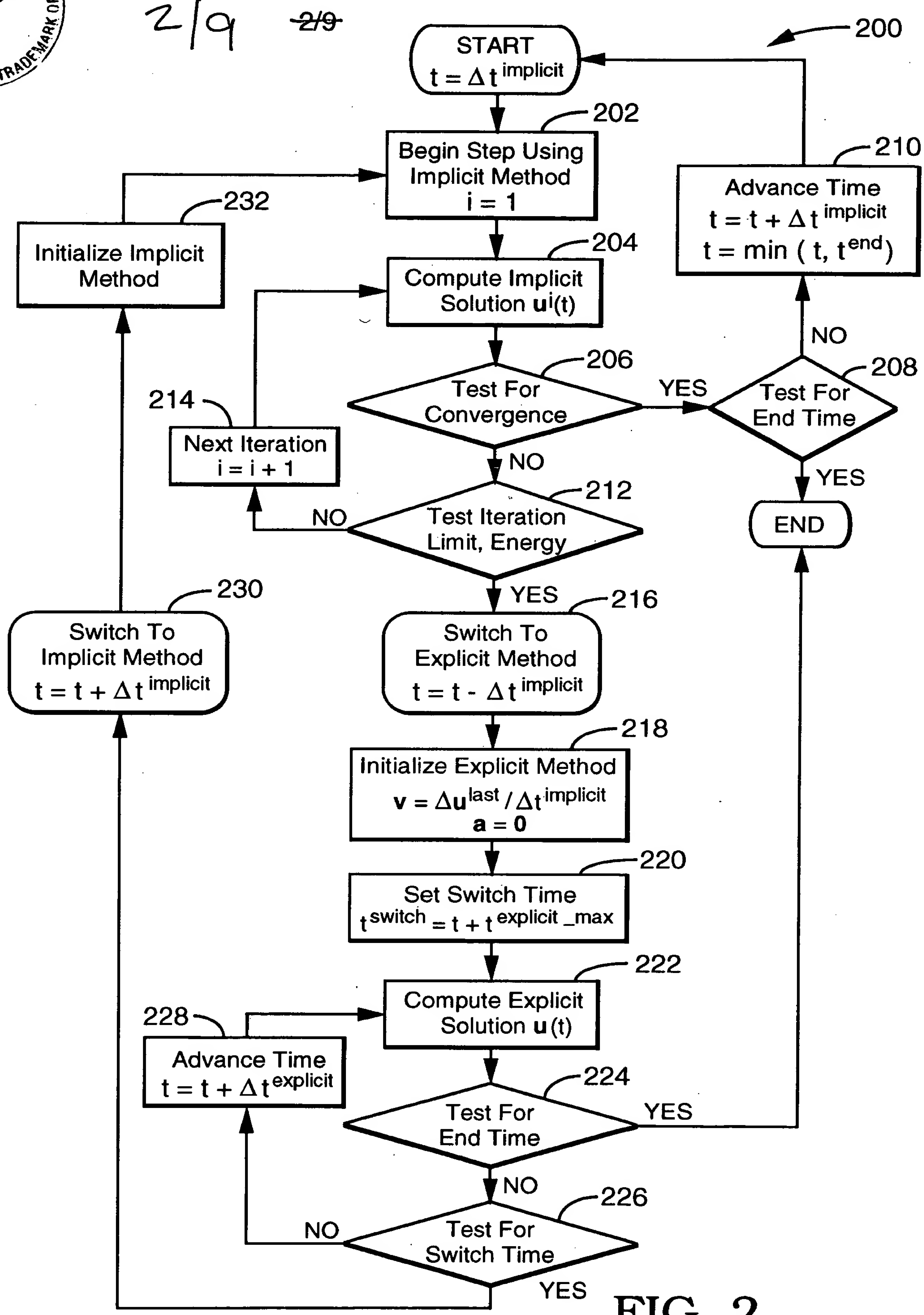
200
START
$t = \Delta t^{implicit}$
202
Begin Step Using Implicit Method
i = 1
204
Compute Implicit Solution $\mathbf{u}^i(t)$
206
Test For Convergence
YES
NO
208
Test For End Time
NO
YES
210
Advance Time
$t = t + \Delta t^{implicit}$
$t = \min(t, t^{end})$
END
212
Test Iteration Limit, Energy
NO
YES
214
Next Iteration
i = i + 1
232
Initialize Implicit Method
230
Switch To Implicit Method
$t = t + \Delta t^{implicit}$
216
Switch To Explicit Method
$t = t - \Delta t^{implicit}$
218
Initialize Explicit Method
$\mathbf{v} = \Delta \mathbf{u}^{last} / \Delta t^{implicit}$
$\mathbf{a} = \mathbf{0}$
220
Set Switch Time
$t^{switch} = t + t^{explicit\_max}$
222
Compute Explicit Solution $\mathbf{u}(t)$
224
Test For End Time
YES
NO
226
Test For Switch Time
NO
YES
228
Advance Time
$t = t + \Delta t^{explicit}$

FIG. 2

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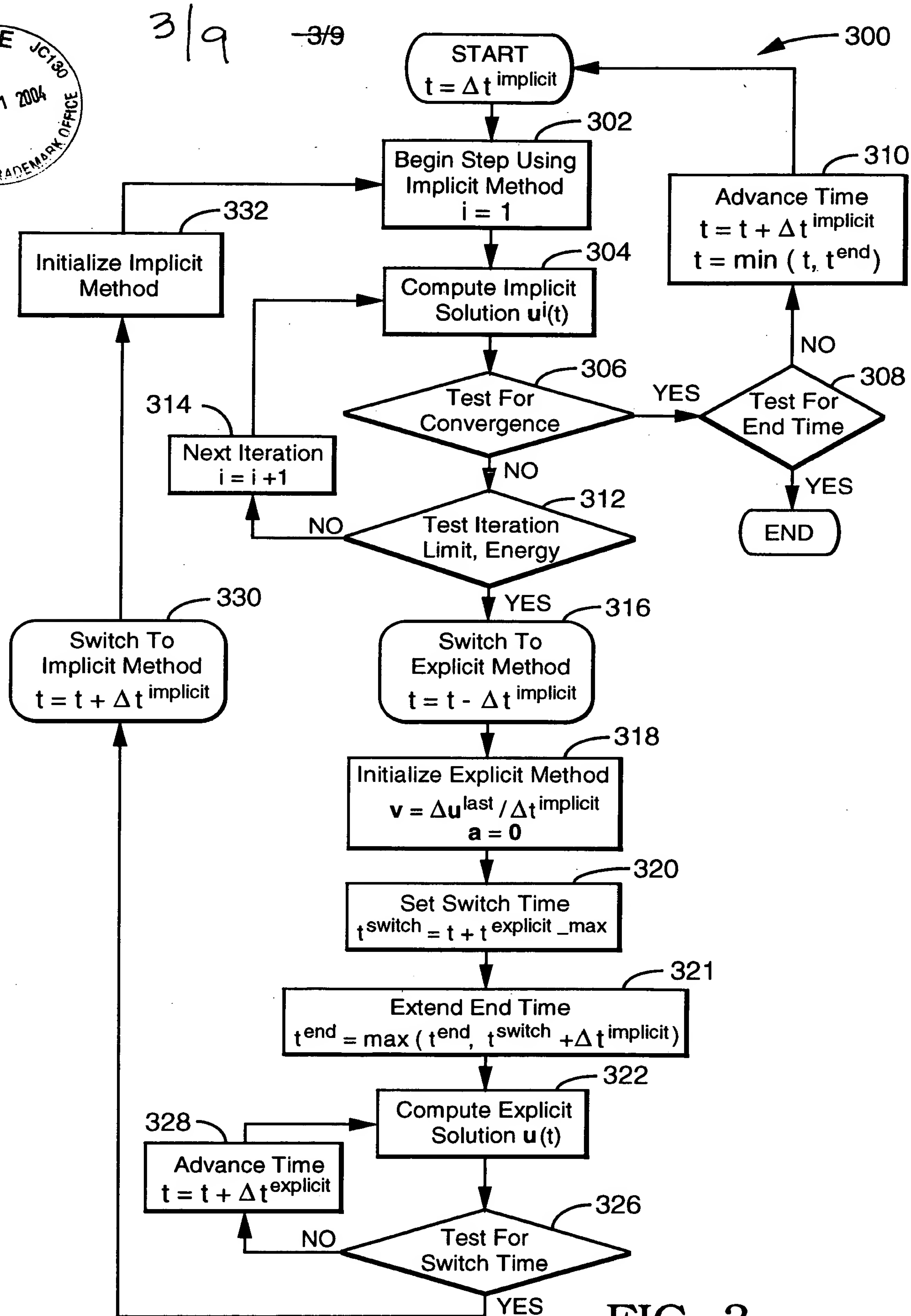
300
START
t = Δt implicit
302
Begin Step Using Implicit Method
i = 1
304
Compute Implicit Solution u^i(t)
306
Test For Convergence
YES
NO
308
Test For End Time
NO
YES
310
Advance Time
t = t + Δt implicit
t = min (t, t end)
END
314
Next Iteration
i = i +1
312
Test Iteration Limit, Energy
NO
YES
332
Initialize Implicit Method
330
Switch To Implicit Method
t = t + Δt implicit
316
Switch To Explicit Method
t = t - Δt implicit
318
Initialize Explicit Method
v = Δu last / Δt implicit
a = 0
320
Set Switch Time
t switch = t + t explicit _max
321
Extend End Time
t end = max (t end, t switch +Δt implicit)
322
Compute Explicit Solution u (t)
328
Advance Time
t = t + Δt explicit
326
Test For Switch Time
NO
YES

FIG. 3